Computed Maximum. 371 Days (C_1).	373·47 Days (C_2).	Observed Maximum (O).	O−C_1 Days.	O−C_2 Days.
1886 Dec. 13	Dec. 12	Dec. 12	− 1	0
1887 Dec. 19	Dec. 20	Dec. 20	+ 1	0
1888 Dec. 24	Dec. 27	Dec. 29	+ 5	+2
1889 Dec. 30	Jan. 5	Jan. 9	+10	+4
1891 Jan. 5	Jan. 13	Jan. 19	+14	+6
1892 Jan. 11	Jan. 22	Jan. 29	+18	+7
1893 Jan. 16	Jan. 29	Feb. 4	+19	+6
1894 Jan. 22	Feb. 7	Feb. 8	+17	+1

There seem to be indications of an inequality in the period from both series of observations. Dr. Chandler, in his elaborate *Second Catalogue of Variable Stars*, notes "periodic inequality" against this star, although the terms have not yet been determined. He points out that inequalities in the variation of long-period variables are in general periodic, running through cycles of fifty or sixty periods on the average, sometimes of only twenty or thirty periods. It is hence pretty evident that we shall require a series of observations of this star extending over a considerable number of years before the period can be properly thrashed out.

I have prepared curves showing the variation in brightness for six seasons, dealing with it when higher than the 9th magnitude. They all show a pretty rapid rise to maximum, and a comparatively gradual declension subsequently. Also curious small fluctuations of light at times, especially when close to the maximum. In fact, the light curve bears a remarkable similarity to that of *Mira Ceti*, except that the rise to maximum of the latter star does not seem quite so sharp.

Gibraltar:
1894 *April* 16.

On the Semi-Annual Variation of Meteors.
By George C. Bompas.

(*Communicated by A. Cowper Ranyard.*)

In 1857 I addressed a paper to the Royal Astronomical Society on the horary variation of shooting stars (*Monthly Notices*, vol. xvii. p. 148).

According to the observations of M. Coulvier Gravier (*Recherches sur les Etoiles Filantes*, Paris, 1845; *Recherches sur les Météores*, Paris, 1859) and of other astronomers, the

average number of shooting stars seen increases from the evening to the morning hours.

This increase was explained in the paper to be due to the rotation of the Earth, and to the fact that the front of the Earth in her orbital motion would encounter more shooting stars than the back, as the front of a man's hat who runs through rain will get wetter than the back, and this in proportion to his speed.

At 6 P.M. the spectator stands at the back of the Earth, and looks back on the track already traversed. The Earth's rotation carries him round hour by hour till at midnight he enters the front hemisphere, and is again carried round until at about 6 A.M. he reaches the foremost meridian of the Earth in her motion along her orbit. To this chiefly is due the variation in the number of meteors from hour to hour.

The results of this paper were in the same year brought before the British Association by the Rev. Baden-Powell (*Report on Luminous Meteors*, 1857, p. 181).

In 1864 a paper by Professor Alex. S. Herschel, "On the State of Meteoric Science," was read to the Royal Astronomical Society (*Monthly Notices*, vol. xxiv. p. 133).

Professor Herschel's paper dealt with the semi-annual variation of meteors. "It is a saying of Arago," he wrote, "founded upon observation and confirmed by constant experience in later years, that the Earth encounters more shooting stars in going from aphelion to perihelion than in going from perihelion to aphelion."

The observations of Dr. Schmidt were cited, extending over eight years (1842 to 1850), and giving an average of 400 for the last six months, and only seventy for the first six months.

The table given, being founded on the total number of meteors observed in each month, requires correction by the number of days of observation, also given by Dr. Schmidt. When so corrected the proportion of meteors visible in the different months, according to his observations, appear to be as follows :

TABLE I.

Schmidt, 1842–1850.

Jan.	2·4	July	4·5
Feb.	1·2	Aug.	11·7
March	1·8	Sept.	3·1
April	1·8	Oct.	3·7
May	1·3	Nov.	5·3
June	1·7	Dec.	3·6
	10·2		31·9

the number in the second half-year being about three times that of the first half-year.

Professor Herschel suggested that this semi-annual variation was probably due to the planetary motion of the Earth, which might be expected to cause a season of frequency of meteors *in all latitudes* three months later than the summer season of the Sun. The northern hemisphere being in front of the Earth from June to December should encounter a larger number of meteors than between January and June, while in the southern hemisphere the season of frequency should be reversed.

Professor Pritchard discussed and adopted this explanation, which he observed depended on a similar principle to that of the horary variation; but pointed out that this theory would be tested by the result of observations in the southern hemisphere, where the same cause should make a corresponding but contrary variation, since the greater number of meteors should in the southern hemisphere appear in the *first* half of the year, when the southern hemisphere is in front of the Earth's orbital motion.

Professor Schiaparelli, in his treatise on meteors (abstracted in the British Association *Report on Luminous Meteors*, 1868, p. 408), adopts the same explanation of the semi-annual variation, and illustrates it by "supposing a meteoric sun or central radiant point of shooting stars to be situate at the apex of the Earth's way, whose rising and setting produce a meteoric morning and evening, and its culmination a meteoric noon and night, six hours before the corresponding change of the Sun—a meteoric spring and autumn, summer and winter, are a consequence of the varying declination (or meridian altitude) of the same meteoric sun, and accordingly follow three months after the corresponding tropical seasons of the year."

The horary and semi-annual variation of meteors have been recently fully discussed in the same sense by Professor Norman Lockyer in his *Meteoric Hypothesis*, chap. xii. p. 125.

The fact of the semi-annual variation is confirmed by many observers.

M. Coulvier Gravier, in his first work (1845), p. 172, gives the mean horary number of meteors for midnight as 3·4 in the first six months, and 8 in the second six months of the year, the latter figure being about two and a half times greater than the former, this average being deduced from the following table of his observations for the years 1841 to 1845:

TABLE II.

Coulvier Gravier, 1841–1845.

	1841.	1842.	1843.	1844.	1845.	Mean Number.
Jan.	...	5·6	3·4	3·3	3·7	3·6
Feb.	...	3·5	2·2	4·0	3·8	3·6
Mar.	...	2·3	3·4	2·6	...	2·7
Apr.	...	3·9	5·1	3·4	...	3·7
May	...	2·7	5·0	2·1	...	3·8
June	...	3·7	2·0	3·3	...	3·2
July	14·7	4·0	3·7	8·1	...	7·0
Aug.	7·0	11·9	9·4	5·4	...	8·5
Sept.	7·8	10·1	5·1	5·2	...	6·8
Oct.	5·6	9·0	3·7	11·4	...	9·1
Nov.	5·2	11·3	5·4	10·7	...	9·5
Dec.	6·6	8·5	10·0	5·4	...	7·2

In his second book, at p. 218, he gives the figures more exactly from twelve years' observation (1846 to 1857 inclusive), corrected for a clear sky, as 5·2 for the first half-year and 13·6 for the second half-year, with the same result of two and a half times the number for the first half-year. He also gives the horary variation for the first and second half-years separately as follows:

TABLE III.

Coulvier Gravier, 1846–1857.

	First Half-year.	Second Half-year.	Mean Number.
5 to 6 P.M.	8·5	7·0	7·2
6 „ 7 „	3·1	6·5	6·5
7 „ 8 „	3·4	8·5	7·0
8 „ 9 „	2·7	8·4	6·3
9 „ 10 „	3·2	11·0	7·9
10 „ 11 „	3·1	12·1	8·0
11 „ 12 „	4·1	13·3	9·5
12 „ 1 A.M.	5·2	14·5	10·7
1 „ 2 „	6·6	17·0	13·1
2 „ 3 „	8·1	20·4	16·8
3 „ 4 „	6·7	18·7	15·6
4 „ 5 „	6·2	18·4	13·8
5 „ 6 „	6·8	18·4	13·7
6 „ 7 „	6·1	17·2	13·0

This table shows also that the horary variation is more rapid in the second half of the year than in the first, being about twice in the first half-year against an increase of three times in the second half-year. It also shows that the maximum is in each half-year not at 6 A.M., but between 2 and 3 A.M., and therefore that the path of the meteor is not directly opposed to that of the Earth, but is in each half-year drawn in towards the Sun.

Mr. Denning gives the following table of the horary numbers of meteors in the several months of the year as the result of his own observations, making the numbers in the second half-year nearly double those in the first half-year. He also found the maximum to be between 2 and 3 A.M. (*Monthly Notices*, vol. l. p. 410.) In his table the Perseids are omitted from the computation.

TABLE IV.

Denning.

Jan.	6·5	July	11·3
Feb.	4·9	Aug.	11·3*
Mar.	6·6	Sept.	10·3
Apr.	6·6	Oct.	11·8
May	5·2	Nov.	11·3
June	4·9	Dec.	8·9
	34·7		64·9

There can be no doubt that the change in the position of the Earth's axis relatively to her motion must, as pointed out by Professor Herschel, tend to increase the number of shooting stars seen in the second half of the year in the northern hemisphere; but this cause has always appeared to me insufficient to account for the very large increase observed—viz. from two to three times the number observed in the first half of the year. This cause, so far as it has operation, depends upon precisely the same principle as the horary variation—viz. the change of the observer's position upon the surface of the globe relatively to the point towards which the Earth is moving.

The horary variation, which is also an increase of about two and a half times, shows that a change in the observer's position of about 180° in longitude is required to increase the horary number two and a half times. How can a change in the distance of the observer from the ecliptic, which at its maximum in passing from the autumnal to the vernal equinox amounts to only 47°, produce, not only at the equinoxes but throughout the half-year, an effect equal to a change of longitude of 180°?

The observations of Dr. Neumayer at the Melbourne Observatory for the years 1858 to 1863 appear sufficiently to

* Perseids omitted.

show that the change of position of the Earth's axis is not the efficient cause of the semi-annual variation of meteors, since this variation in the southern hemisphere is not in fact reversed, but follows the same law as in the northern, the hourly number of meteors seen in the second half of the year exceeding the number seen in the first half-year.

In Dr. Neumayer's *Report of Meteorological Observations at the Flagstaff Observatory, Melbourne, for the Years* 1858–1863, vol. iii. p. 141, the monthly horary numbers of meteors are given from observations of upwards of 2,000 meteors as follows :

TABLE V.

Neumayer, 1858–1863.

Jan.	2·2	July	3·2
Feb.	1·8	Aug.	3·2
Mar.	1·6	Sept.	2·8
Apr.	1·4	Oct.	3·0
May	2·0	Nov.	2·2
June	3·0	Dec.	2·9
	12·0		17·3

This makes the average horary number for the first half-year 2, and for the second half-year 2·9, the numbers for the second half-year being nearly 50 per cent. greater than for the first half-year.

The small numbers given for each hour show that these observations are not very complete. A statement in vol. ii. of Dr. Neumayer's reports shows that the number of hours of observation averaged only seventeen per month. The horary number given cannot, therefore, be considered exact.

The smaller increase recorded in the Melbourne Observatory may be partly accounted for by the fact that the numbers are not corrected with reference to the state of the sky. Dr. Neumayer notes particularly that in the month of November the weather was so unfavourable that it was impossible to determine in a reliable manner whether the November star shower was visible. A correction for the state of the sky might therefore considerably increase the numbers for the second half of the year.

Some difference will be due also to the alteration in the position of the Earth's axis, as already shown, which in the southern hemisphere would cause a deduction from any increase in the second half-year due to a cause common to both hemispheres.

The Melbourne observations are, however, sufficient to prove that the semi-annual variation of meteors follows the same law of an increase in the second half-year in the southern as in the northern hemisphere. It must, therefore, have some other or

further cause than that hitherto assigned—namely, the change of position of the Earth's axis.

A probable cause of the semi-annual variation of meteors may be found in the cosmical motion of the solar system, which renders the absolute motion of the Earth swifter in the first half of the year, while passing to aphelion, than in the second half of the year, while passing to perihelion, and would tend, therefore, to cause a semi-annual variation in the number of meteors encountered.

If meteors were at rest in space, and were encountered by the solar system, there would be a semi-annual variation contrary to that observed, the larger number of meteors being encountered by the Earth in the first half of the year, when her motion is swiftest.

If, however, the majority of meteors are assumed to have a proper motion, in a direction similar to but swifter than that of the Sun, the conditions would be reversed, and the larger number of meteors would be seen in the second half of the year, when the relative motion of meteors and the Earth would be greatest, consisting then of the sum of their velocities when meeting one another, instead of the difference of those velocities, as in the first half of the year.

If, for example, the motion of the Sun is assumed at 10 miles per second, and that of the meteors as equal to the Earth's orbital motion, say 18 miles per second, then at the vernal equinox the Earth would overtake the meteors with a velocity of $18 + 10 - 18 = 10$ miles per second, while at the autumnal equinox the Earth would meet the meteors with a relative velocity of $18 - 10 + 18 = 26$ miles per second.

Such a proper motion of meteors cannot, however, generally exceed the absolute motion of the Earth in the first half of the year, otherwise meteors would then overtake the Earth, and the horary variation would be reversed, the larger number of meteors being encountered in the evening hours.

If the semi-annual variation of meteors is due to the cosmical motion of the solar system, we must attribute to meteors an independent cosmical motion, and a cosmical origin.

The cosmical origin of meteors may with some probability be inferred from their number, if, as has been estimated, 20,000,000, or, if telescopic meteors are included, 400,000,000, are daily consumed in our atmosphere, besides the larger numbers absorbed by the other planets and by the Sun; yet the horary number shows no diminution.

That the relative motion of meteors and the Earth is in fact greater in the second half of the year may be inferred from M. Coulvier Gravier's observations (Table III.), which show that the horary variation of meteors is more rapid in the second half of the year.

If a proper motion of meteors may be assumed—and motion, not rest, is the law of the universe—the profusion of meteors

between longitude 0° and 60°, as observed by Mr. Denning, may show that the direction of their motion generally follows that of the Sun, and is drawn in towards the Sun.

Mr. Denning says (*Monthly Notices*, vol. 47, p. 39): "Meteors and meteoric radiants display by far the greatest profusion between July and December, and the densest region of radiation lies between 1° and 60° of R.A. This is, indeed, the most active part of the heavens, even as late as November, when it is some 110° distant from the apex of the Earth's way."

The positions of the 918 radiants given in Denning's catalogue (*Monthly Notices*, vol. 50), show about two-thirds grouped in the hemisphere from which the Sun is moving. It must be borne in mind, however, that these observations were chiefly made in the second half of the year.

A diagram at the end of M. Kleiber's treatise on meteor orbits, purporting to give corrected positions for these radiants, shows a more remarkable grouping of meteors behind the Sun's path.

Table VI. shows the apparent positions of the 918 radiants from Denning's catalogue.

Table VII. reproduces M. Kleiber's diagram (see also pp. 258 and 261 of his treatise).

I venture to submit—

1. That the explanation hitherto adopted of the semi-annual variation of meteors is inadequate.

2. That the variation is connected with and mainly due to the cosmical motion of the solar system.

3. That it renders highly probable the cosmical origin and motion of meteors.

1894 *June.*

Motion of Fireballs and Shooting Stars relatively to the Earth.
By W. F. Denning.

That there is a marked distinction in the general direction of motion of fireballs and ordinary shooting stars is a fact which has often impressed itself upon me during the progress of observation. I refer to the frequent tendency of fireballs to indicate radiants which are quite unknown and placed in regions of the sky singularly free from normal showers of shooting stars. In determining the real paths of fireballs from duplicate observations the same feature has been prominently suggested, and has led me incidentally to remark upon it on several occasions. The comparison of a large number of published results with particular regard to the positions of the radiants also bears out this conclusion in a manner not to be mistaken. There is no doubt that the majority